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DISTRIBUTION OF THE NEMATODE PARASITES OF YELLOW PERCH FROM SAGINAW BAY, LAKE HURON

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Jennifer Lynn Rosinski

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Master's degree in Zoology

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Major professor
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DISTRIBUTION OF THE NEMATODE PARASITES OF YELLOW PERCH FROM SAGINAW BAY, LAKE HURON

By

Jennifer Lynn Rosinski

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Zoology

1994

ABSTRACT

DISTRIBUTION OF THE NEMATODE PARASITES OF YELLOW PERCH FROM SAGINAW BAY, LAKE HURON

By

Jennifer Lynn Rosinski

A total of 270 yellow perch, _Perca flavescens_, was examined for nematodes in May and September 1992 from four locations in Saginaw Bay, Lake Huron, and in October 1993 from one location in Lake St. Clair. Composition, prevalence and intensity of the nematode fauna of yellow perch differed between Saginaw Bay and Lake St. Clair. The study locations in Saginaw Bay varied in biotic and abiotic characteristics. Prevalences and intensities of nematodes varied with location and month of yellow perch collection. Distributions of _Eustrongylides tubifex_, _Philometra cylindracea_, _Dichelyne cotylophora_, and _Raphidascaris_ sp. appear to be influenced by the distributions of intermediate and paratenic hosts and by the life histories of the perch and the nematodes. Larger and older yellow perch had higher prevalence and intensity of _E. tubifex_. Intensity of _Raphidascaris_ sp. also increased with host length. High prevalence and intensity of _E. tubifex_ indicate that yellow perch from Saginaw Bay should not be used for stocking purposes.

ACKNOWLEDGMENTS

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INTRODUCTION

Many abiotic and biotic factors are important in determining the distribution of a parasite fauna in animals of an aquatic ecosystem (Esch 1971). Physical characteristics of a lake may influence parasite assemblage and abundance found within the animals (Wisniewski 1958; Esch 1971; Marcogliese and Cone 1991). While it is not possible to study the effects of all abiotic and biotic components that may influence parasite distribution and abundance, a few obvious parameters include: water quality, distribution of intermediate and definitive hosts (Esch 1971; Kaeding 1981; Hirshfield *et al.* 1983; Measures 1988b; Marcogliese and Cone 1991) and time of year of host collection (Dogiel 1962).

Lake water quality influences the parasite fauna in many ways. Animal assemblages are ultimately determined by trophic conditions of the system and parasite fauna is closely linked to the animals present (Wisniewski 1958; Esch 1971). Trophic conditions also influence the distribution of animals that may serve as hosts throughout the ecosystem (Esch 1971; Kaeding 1981; Hirshfield *et al.* 1983; Measures 1988b; Marcogliese and Cone 1991).

In addition to lake characteristics, host life history traits and those of the parasites are important in determining parasite abundance and distribution (Stromberg and Crites 1975). The host diet is an important life history trait that directly influences the parasite fauna (Dogiel 1962). Life history characteristics of nematodes, such as direct or indirect life cycles, also contribute to success of the parasite (Stromberg and Crites 1975).

Yellow perch, Perca flavescens Mitchill 1814 (Percidae), spawn in the spring and juveniles hatch in mid-May (Keast 1977; Diana and Salz 1990). Age 0 yellow perch initially feed on small crustaceans such as copepods. The diet then progresses to benthic fauna including oligochaetes, insect larvae, large crustaceans, and mollusks. As the perch grow, they eventually begin to feed on crayfish and fish (Clady 1974; Keast 1977; Leach *et al.* 1977; Thorpe 1977). Males typically mature in their third year and females in their fourth. In Saginaw Bay, Lake Huron, yellow perch exhibit slow growth, mature at early age, and have high mortality past age IV (Salz 1989; Diana and Salz 1990).

Yellow perch are important intermediate and definitive hosts for several nematode species. Yellow perch are second intermediate hosts for Eustrongylides tubifex (Nitzsch 1819) Jagerskiold 1909 (Nematoda: Dioctophymatidae). This nematode develops to the fourth stage larva in yellow perch and most often encysts in their mesenteries (Cooper *et al.* 1978; Measures 1988b). Yellow perch acquire E. tubifex by ingesting infected tubificid oligochaetes. The most important oligochaetes in the life cycle of E. tubifex are Limnodrilus hoffmeisteri Claparede 1862 and Tubifex tubifex Muller 1774. The larvae develop to the third stage in the oligochaete and are then infective to fish (Lichtenfels and Stroup 1985; Measures 1988a, 1988b). After developing to fourth stage larvae in fish, E. tubifex is infective to piscivorous bird definitive hosts such as the common merganser, Mergus merganser Linnaeus, and the red-breasted merganser, Mergus serrator L. (see Crites 1982; Measures 1988b, 1988c). Eustrongylides tubifex develops rapidly in the proventriculus of the bird. Thus, migratory birds arriving at Saginaw Bay can acquire E. tubifex and begin passing eggs within a short time of exposure to the nematode (Crites 1982; Measures 1988b, 1988c).

Yellow perch have been found to be the most important hosts of E. tubifex in Lakes Huron and Erie (Allison 1966; Cooper *et al.* 1978; Crites 1982). Other fish, however, have also been reported as hosts. In Lake Huron, banded killifish, Fundulus diaphanus LeSueur, and smallmouth bass, Micropterus dolomieu Lacepede, have been reported as hosts (Dechtiar *et al.* 1988). Channel catfish, Ictalurus punctatus Rafinesque, freshwater drum, Aplodinotus grunniens Rafinesque, and smallmouth bass have been found infected with E.tubifex in Lake Erie (Cooper *et al.* 1978). Eustongylides tubifex also has been found in yellow perch from Lakes Ontario (Nepszy 1988) and Michigan (Muzzall *unpublished data*), but have low infection values, and Eustrongylides spp. have been reported from fish throughout North America (Taub 1968; Cooper *et al.* 1978; Kaeding 1981; Bursey 1982; Measures 1988b). Eustrongylides tubifex can be transferred from one fish host to another as a result of predation on smaller infected fish (Cooper *et al.* 1978; Crites 1982; Measures 1988b). Therefore, many fish species act as paratenic hosts for E. tubifex.

Yellow perch are the definitive hosts for Philometra cylindracea (Ward and Magath 1917) van Cleave and Mueller 1934 (Nematoda: Philometridae). This nematode has a one year life cycle in fish. Fish obtain third stage larvae by eating infected cyclopoid copepods such as Cyclops vernalis Fischer and other Cyclops spp. Muller 1785. The larvae develop to the fifth stage and mature in the perch body cavity (Molnar and Fernando 1975; Crites 1982). Gravid female P. cylindracea penetrate the body wall and project into the water where they rupture due to change in osmotic pressure. Larvae released when the worm bursts are eaten by copepods in which they reach the infective third stage (Molnar and Fernando 1975; Crites 1982). In addition to Lake Huron, P. cylindracea has been found in yellow perch from Lakes Erie and Ontario (Nepszy 1988). Pearse (1924) found this nematode in yellow perch from Lake Michigan, but it was not found in later studies (Amin 1977; Muzzall *unpublished data*).

Yellow perch are the most important definitive hosts for Dichelyne cotylophora (Ward and Magath 1917) Petter 1974 (Nematoda: Cucullanidae). Dichelyne cotylophora lives for one year in perch. Small prey fish such as minnows ingest eggs or third stage larva of D. cotylophora; the larvae develop to infective fourth stage and encyst in the livers of the intermediate hosts. Within the definitive host, fourth stage D. cotylophora larvae develop to fifth stage and mature in the intestinal lumen (Baker 1984b). Eggs are released into the water with host feces; by feeding on the eggs the intermediate hosts may become infected. Aquatic invertebrates have been shown to be hosts for other cucullanid nematodes and may act as paratenic hosts for this nematode (Baker 1984b). Yellow perch are important hosts for D. cotylophora in all of the Great Lakes (Pearse 1924; Amin 1977; Nepszy 1988).

Invertebrates such as chironomids, amphipods, and oligochaetes act as paratenic hosts for Raphidascaris sp. Railliet and Henry 1915 (Nematoda: Anisakidae), while yellow perch and other fish are first intermediate hosts. Yellow perch become infected by ingesting eggs or second stage larvae, or by feeding on infected paratenic hosts. Raphidascaris sp. larvae occur within yellow perch either encysted in the liver or intestinal wall (Moravec 1970a, 1970b; Smith 1984b). Here, they develop to the infective fourth stage. The definitive hosts, northern pike, Esox lucius L., rainbow trout, Oncorhynchus mykiss Wabaum, and brook trout, Salvelinus fontinalis Mitchill, become infected by consuming infected perch (Smith 1984b). Adult worms become established in the intestine or pyloric cecae of definitive hosts and their eggs are passed with the host feces (Moravec 1970a, 1970b; Smith 1984b). Yellow perch from Lakes Huron, Michigan and Superior have been found to be hosts for Raphidascaris sp. (Nepszy 1988; Muzzall *unpublished data*).

The interaction of life histories of hosts and parasites with water quality and distribution of intermediate and definitive hosts influences parasite abundance and distribution. Saginaw Bay exhibits variation in depth, water quality, and composition of hosts, providing interesting study locations to compare parasite distribution and abundance. Because Lake St. Clair is more oligotrophic, it provides an interesting comparison to Saginaw Bay.

One objective of this study was to gather information on nematode distribution in yellow perch from Saginaw Bay. Except for studies done by Allison (1966) and Salz (1989) on E. tubifex[1], little is known about the nematode fauna of yellow perch from Saginaw Bay. Salz (1989) calculated prevalence but not intensity of infection in yellow perch from several Saginaw Bay locations. Bangham (1955) and Dechtiar *et al.* (1988) surveyed the parasite fauna of Lake

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[1]Allison (1966) identified the nematode as Philometra cylindracea, but it is now known that the nematode he studied was Eustrongylides tubifex (R. Haas, Michigan Department of Natural Resources, *personal communication*).

Huron fishes including yellow perch, but the locations studied did not include Saginaw Bay. Bangham (1955) obtained fish from South Bay, Lake Huron proper and lakes on Manitoulin Island. Although he found several nematode species, E. tubifex was not found in yellow perch. Dechtiar *et al.* (1988) studied fish from Lake Huron and found E. tubifex in addition to other nematode species. Allison (1966) thought that Saginaw Bay had the highest abundance of E. tubifex in the Great Lakes, but he studied only one location in inner Saginaw Bay. Thus, it is concluded that there is little basic information on the nematodes infecting yellow perch from Saginaw Bay.

The redworm nematodes E. tubifex and P. cylindracea reduce the growth rate of yellow perch (Crites 1982; Salz 1989) and it is also thought that fish mortality may result from redworm infection (Allison 1966; Crites 1982). Using infected fish to stock culture ponds may facilitate the transfer of these nematodes to new locations. Thus, the impact of moving infected yellow perch from Saginaw Bay to other locations could be very detrimental to animals associated with the new locations.

The specific goals of this study were (1) to provide basic data on the nematode fauna of yellow perch collected in Saginaw Bay, including the influence of host size, age and sex on nematode abundance; (2) to compare nematode distribution in yellow perch collected from Lake St. Clair and different locations in Saginaw Bay; (3) to make recommendations about using yellow perch from the study areas for stocking other systems.

MATERIALS AND METHODS

Description of Nematodes

Eustrongylides tubifex fourth stage larvae are primarily encysted in round yellow capsules in fish mesenteries. Larvae are bright red and have prominent circumoral papillae. Fourth stage larvae have only 6 visible papillae (Measures 1988b). Female fourth stage larvae (45.1 mm - 83.4 mm) are longer than males (32.2 mm - 66.0 mm) but female and male third stage larvae are approximately the same length. Fourth stage male and female genital tubes extend anteriorly almost to the esophageal-intestinal junction. The male genital tube terminates in a large, blunt, hologonic testis; the female genital tube curves posteriorly and terminates in a tapering, hologonic ovary (Measures 1988a).

Philometra cylindracea typically is in the body cavity under the air bladder serosa (Molnar and Fernando 1975; Ashmead and Crites 1975). Immature worms are white with a rounded anterior end with four inconspicuous circumoral papillae. The esophagus forms a bulb near the mouth (Molnar and Fernando 1975). The didelphic uterus has one branch extending anteriorly and one posteriorly (Molnar and Fernando 1975; Ashmead and Crites 1975). Ranges in lengths for mature females and larvigerous females are 1.9 mm - 3.8 mm and 92.6 mm - 154 mm, respectively (Ashmead and Crites

1975). Males are infrequent. None were found in the present study.

Dichelyne cotylophora are found in the intestine of fish. They have a thick body cuticle and the esophagus is wide at the anterior and posterior ends. The oral opening is surrounded by a raised collar of rib-like thickenings. Males possess a pseudosucker and several pairs of caudal papillae. Females have uteran branches which converge from opposite directions and a pair of phasmids near the middle of the tail. Size range of the larvae is 1.1 mm - 7.2 mm (Baker 1984a).

Fourth stage larvae of _Raphidascaris_ sp. commonly are encysted in the liver of fish but also encyst in the intestinal wall and mesenteries. _Raphidascaris_ spp. have a small appendix attached to the posterior portion of the esophagus. They have three lips with small triangular interlabia. The cuticle has distinct striations. Lateral alae extend from the base of the lips to the long, conical, pointed tail. Fourth stage larvae collected from yellow perch range in size from 2.4 mm - 3.9 mm (Smith 1984a). _Raphidascaris_ sp. from the present study is thought to be _R. acus_ (Bloch 1779) Railliet and Henry 1915 based on the presence of lateral cuticular flanges present near the lips that distinguish _R. acus_ from all other _Raphidascaris_ spp. (Smith 1984a, 1984b). This identification was based on fourth stage larvae only and the nematode will here be referred to as _Raphidascaris_ sp.

Adult Camallanus oxycephalus Ward and Magath 1917 (Nematoda: Camallanidae), typically found in the fish intestine, have a bronze colored buccal capsule with longitudinal ridges. Dorsal and ventral trident-shaped chitinous processes project posteriorly from the buccal capsule. The esophagus has muscular and glandular portions. Male posterior extremity is rolled ventrally; thin caudal alae and numerous pre-anal and post-anal papillae are present; spicules are unequal and one is highly sclerotized. Female has opposed uteri (Hoffman 1967; Stromberg *et al.* 1973).

Haplonema sp. Ward and Magath 1917 (Nematoda: Haplonematidae) larvae are found encysted in the stomach wall and mesenteries. They have no buccal capsule and the esophagus is divided into muscular and glandular parts. Males have pre-anal and post-anal papillae but no caudal alae; spicules are equal. Females have two small papillae on the posterior body and opposed uteri (Hoffman 1967).

Adult Rhabdochona sp. Railliet 1916 (Nematoda: Rhabdochonidae) are usually located in the fish intestines. The mouth has two lips. Buccal capsule is funnel shaped with longitudinal ribs and anteriorly pointed teeth. The esophagus has muscular and glandular portions. Males are spirally coiled posteriorly; narrow caudal alae, numerous pre-anal and several pairs of post-anal papillae are present; spicules are unequal. Females have straight tails and opposed uteran branches (Hoffman 1967).

Description of Study Locations

Saginaw Bay is the southwestern extension of Lake Huron located in east central Michigan. It is a large, shallow, eutrophic bay divided into inner and outer bays by a constriction near Point Lookout and Sand Point (Figure 1) (Dolan *et al.* 1986). The inner bay is enriched with domestic, agricultural, and industrial inputs from the Saginaw River (Michigan Department of Natural Resources 1988; Salz 1989). Historically, Saginaw Bay and the Saginaw River have served as major fish spawning and nursery areas and as refuges and food sources for many migratory and non-migratory birds (Michigan Department of Natural Resources 1988). The inner bay, with a mean depth of 4.6 meters, is shallower than the outer bay.

Yellow perch were collected from four locations in the inner bay: Blackhole, North Island Point, Au Gres, and Fish Point (Figure 1). Differences between the study locations include water depth, water quality, and other physical factors (Salz 1989). Blackhole, the deepest of the locations, is located closest to the mouth of the Saginaw River making it the most eutrophic location. North Island Point and Au Gres are the shallowest stations. Because of their close vicinity to the outer bay, these locations exhibit higher water quality and well mixed outer bay characteristics. Fish Point has less organic sediments and is less eutrophic than Blackhole.

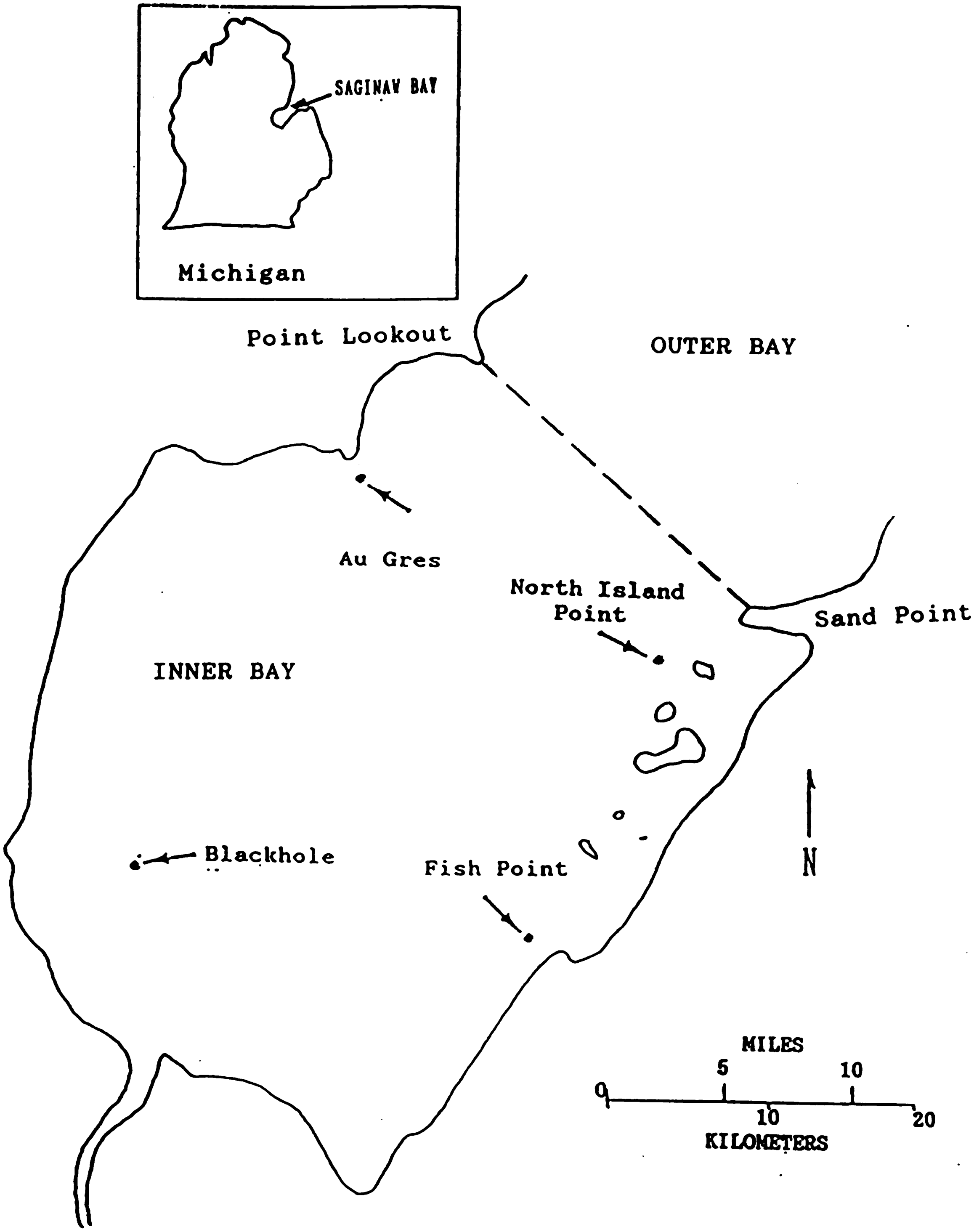

Figure 1. Inner and outer bays of Saginaw Bay, Lake Huron with yellow perch collection locations from inner Saginaw Bay 1992. (Figure re-drawn based on Michigan Department of Natural Resources 1988 and Salz 1989.)

Large amounts of organic sediments at Blackhole support an abundance of benthic invertebrates. Schneider *et al.* (1969) found oligochaetes concentrated in this area and Brinkhurst (1967) reported that areas around Blackhole contained the highest percentages of tubificid oligochaetes in Saginaw Bay. Copepods such as Cyclops spp. are most abundant near the mouth of the Saginaw River, so that areas in the inner bay near Blackhole should have the highest numbers of cyclopoid copepods (Michigan Department of Natural Resources 1988).

Distribution of amphipods and chironomids varies in inner Saginaw Bay. Few species and numbers of amphipods are present, but some species predominate in shallow water zones. Chironomids are abundant in deeper waters of the inner bay, especially in areas where organic materials accumulate. However, several chironomid species are common throughout the bay and are highly concentrated in the Blackhole and Au Gres areas (Schneider *et al.* 1969). Chironomus spp. Meigen 1803 are pollution-tolerant and are among the most abundant zoobenthic taxa in Saginaw Bay (Michigan Department of Natural Resources 1988).

Dolan *et al.* (1986) and Michigan Department of Natural Resources (1988) provide a more detailed description and a summary of the physical, chemical and biological data for Saginaw Bay.

Lake St. Clair is a small, shallow connecting body of water between the St. Clair and Detroit Rivers on the eastern side of Michigan (Figure 2). It has a surface area of 1114 square kilometers and a mean depth of 3 meters, but it has a maximum depth of 8 meters along a dredged shipping channel. Lake St. Clair is fed primarily with waters from southern Lake Huron through the St. Clair River. Thus, Lake St. Clair exhibits similar water quality to Lake Huron (Bolsenga and Herdendorf 1993). The southern portion of Lake Huron is oligotrophic with slightly nutrient enriched areas near shore (Dolan *et al.* 1986). Yellow perch from Lake St. Clair were collected from Campau Bay which is located on the western side of the lake, south of the Clinton River (J. Hodge, *personal communication*). The results of this collection location may serve as a baseline of comparison for the Saginaw Bay study areas.

Field and Laboratory Methods

Yellow perch were collected by otter trawl with an 11 meter tow rope by the Michigan Department of Natural Resources from four locations in Saginaw Bay, Lake Huron and from one location in Lake St. Clair. Fish were collected from various depths ranging from 2 meters to 9.2 meters. The sampling locations and dates of yellow perch collection were: (1) Fish Point: May 14, 1992 and September 25, 1992; (2) North Island Point: May 14, 1992 and October 1, 1992; (3) Au Gres: May 11, 1992 and September 22, 1992; and (4) Blackhole: May 12, 1992 and September 24, 1992 in Saginaw

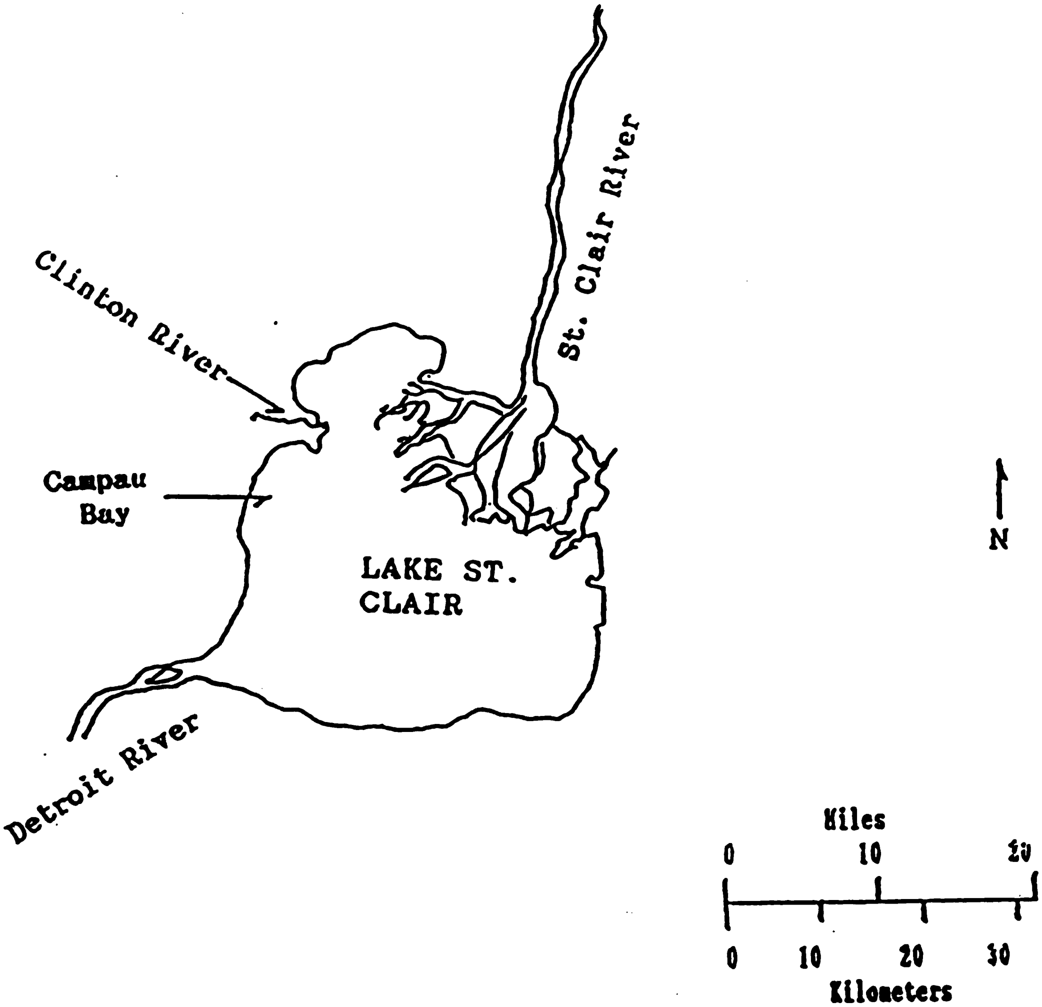

Figure 2. Lake St. Clair. (Figure re-drawn based on Bolsenga and Herdendorf 1993.)

Bay, and (5) Campau Bay, Lake St. Clair: October 7, 1993. The September/October collection dates are referred to as September. Fish were frozen in the field. Thirty yellow perch from each location in each month were examined for a total of 270. The fish were selected randomly from each sample.

Frozen yellow perch were thawed in the laboratory. Total length (mm), weight (g), and sex were recorded at necropsy. Scale samples were taken from the left side below the lateral line near the pectoral fin of each fish for age determination by R. Haas of the Michigan Department of Natural Resources. Eyes, gonads, kidneys, spleen, liver, gall bladder, esophagus, gastrointestinal tract, heart, body cavity, and right or left side of musculature were examined for nematodes. Nematodes were preserved in 70% alcohol and later cleared in glycerine for identification.

Statistical Analysis

Prevalence is the percentage of fish from a sample infected with a nematode species. Intensity is the number of worms per infected fish. Mean intensity is the mean number of worms of a nematode species per infected yellow perch. Mean intensity values are expressed as mean intensity $\pm$ SD.

Chi-square analyses were performed to determine if the number of fish infected with a nematode species was independent of age, length or sex of the fish and year, month, or location of fish collection. Each nematode species was analyzed separately.

Intensity data for each nematode species were not normally distributed and, therefore, were rank transformed (Potvin and Roff 1993) for statistical analyses. Analysis of variance (ANOVA) was performed to ascertain whether fish size and age differed between months and locations. Grouping of fish by length (mm) was decided arbitrarily as follows: < 100, 100-109, 110-119, 120-129, 130-139, 140-149, 150-159, 160-169, $\geq$ 170. Age classes of fish were 0, I, II, III, IV, V. Fish older than V were included with age class V. Multiway ANOVA was used to examine the effects of fish size and age, and month and location of fish collection on nematode intensity. This was used to determine whether individual factors had a significant effect on mean intensity of each parasite and also whether interaction of the factors significantly affected mean intensity. When differences were detected, Tukey test was used to locate the differences. Where no monthly differences were detected, data were combined by location for further analyses.

Linear regression analyses were performed to investigate possible relationships between number of nematodes and yellow perch size and age. All tests were performed at a significance level of $P \leq 0.05$.

RESULTS

Yellow Perch

There was no significant difference in length or weight of yellow perch between different months (length: $F = 0.03$, $df = 1, 236$; weight: $F = 3.7$, $df = 1, 239$; $P \leq 0.05$) or locations (length: $F = 0.6$, weight: $F = 1.4$, $df = 3, 116$; $P \leq 0.05$) in Saginaw Bay (Table 1). Yellow perch from Lake St. Clair (Table 2) were significantly larger than fish from Saginaw Bay (length: $F = 43.4$, weight: $F = 62.5$, $df = 2, 267$; $P < 0.05$). Ages of fish significantly differ between Saginaw Bay and Lake St. Clair samples ($F = 26.4$, $df = 2, 267$; $P \leq 0.05$) (Table 3). Fish from May 1992 in Saginaw Bay had the highest mean age while fish from September 1992 had the lowest mean age. Yellow perch from Lake St. Clair 1993 had an intermediate mean age. There was no significant difference in ages of fish between locations in Saginaw Bay (May: $F = 0.03$, September: $F = 2.6$, $df = 3, 116$; $P \leq 0.05$). Age 0 fish were collected only in September from Saginaw Bay.

Nematodes

A total of six nematode species occurred in yellow perch from Saginaw Bay, Lake Huron. These species were: Eustrongylides tubifex; Philometra cylindracea; Dichelyne

Table 1. Mean yellow perch length (mm), weight (g) and ranges from four locations in Saginaw Bay, Lake Huron 1992. Thirty fish from each location in each month were examined.

	Location			
	Fish Point	North Island Pt.	Au Gres	Blackhole
May 1992				
Length ± SD	127.6 ± 32.2	138.1 ± 10.9	131.9 ± 35.7	130.8 ± 37.4
(min - max)	(68.0 - 163.5)	(122.0 - 166.0)	(64.0 - 186.0)	(65.0 - 203.0)
Weight ± SD	25.4 ± 14.4	31.2 ± 7.3	34.4 ± 20.8	33.0 ± 25.4
(min - max)	(3.2 - 53.2)	(19.5 - 45.5)	(3.2 - 86.9)	(2.5 - 115.0)
September 1992				
Length ± SD	125.8 ± 33.4	123.9 ± 15.1	132.0 ± 18.9	144.4 ± 28.7
(min - max)	(67.0 - 193.0)	(102.0 -167.0)	(106.0 - 188.0)	(108.0 - 210.0)
Weight ± SD	33.6 ± 24.4	26.4 ± 9.8	36.8 ± 20.1	47.1 ± 28.8
(min - max)	(3.8 -102.9)	(15.1 - 57.4)	(19.4 - 118.3)	(17.7 - 107.7)

Table 2. Mean yellow perch length (mm), weight (g), and ranges from Lake St. Clair, October 1993. Thirty fish were examined.

Length ± SD (min - max)	Weight ± SD (min - max)
182.8 ± 173.5 (151.0 - 263.0)	94.2 ± 68.7 (46.8 - 334.5)

Table 3. Mean ages ± standard deviation of yellow perch from Saginaw Bay, Lake Huron 1992 and from Lake St. Clair 1993. There were 120 fish examined in each month in Saginaw Bay and 30 fish from Lake St. Clair.

	Location	
Month	Saginaw Bay	Lake St. Clair
May	3.1 ± 3.0	---
September/October	1.8 ± 1.0	2.4 ± 2.0

cotylophora; Raphidascaris sp.; Camallanus oxycephalus; and a single gravid female nematode was found in the wall of the intestine but, because the anterior end was missing, it was not possible to identify it. Of the 240 yellow perch examined from Saginaw Bay, 215 (90%) were infected with at least one nematode. The numbers (percentages) of yellow perch infected with at least one nematode out of 30 fish from each location in Saginaw Bay in May and September, respectively, were: Fish Point 27 (90%) and 22 (73%); North Island Point 29 (97%) and 25 (83%); Au Gres 28 (93%) and 28 (93%); Blackhole 28 (93%) and 28 (93%).

Six nematode species also infected yellow perch from Lake St. Clair. These species were: E. tubifex; D. cotylophora; Raphidascaris sp.; C. oxycephalus; Haplonema sp.; and Rhabdochona sp. Of the 30 yellow perch examined from Lake St. Clair, 26 (87%) were infected with at least one species of nematode.

Although E. tubifex, D. cotylophora, Raphidascaris sp., and C. oxycephalus were found in both Saginaw Bay and Lake St. Clair, P. cylindracea was present only in Saginaw Bay, and Rhabdochona sp. and Haplonema sp. were present only in Lake St. Clair.

Quantitative differences occurred between Saginaw Bay and Lake St. Clair with E. tubifex, Raphidascaris sp., C. oxycephalus, and D. cotylophora (Table 4, Table 5, Table 6). Prevalence and intensity of E. tubifex

Table 4. Prevalence (%) of nematode infection in yellow perch from four locations in Saginaw Bay, Lake Huron 1992.

		Nematode[‡]				
Location	Month	ET	PC	DC	RS	CO
Fish Point	May	83.3	33.3	----	30.0	----
	September	60.0	13.3	13.3	20.0	----
North Island Pt.	May	90.0	26.7	26.7	66.7	13.3
	September	70.0	36.7	20.0	13.3	----
Au Gres	May	76.7	30.0	36.7	60.0	----
	September	86.7	10.0	43.3	6.7	----
Blackhole	May	86.7	30.0	----	46.7	----
	September	90.0	10.0	13.3	20.0	----

‡ Nematodes: ET = Eustrongylides tubifex; PC = Philometra cylindracea; DC = Dichelyne cotylophora; RS = Raphidascaris sp.; CO = Camallanus oxycephalus.

Table 5. Mean intensity ± standard deviation and maximum number (max) of nematodes in yellow perch from four locations in Saginaw Bay, Lake Huron 1992. (Intensity values are not rank transformed.)

		Location			
Nematode*	Month	Fish Point	North Island Pt.	Au Gres	Blackhole
ET	May	5.3 ± 3.9 (17)	4.3 ± 4.4 (20)	4.8 ± 6.4 (32)	6.0 ± 4.9 (13)
	September	5.7 ± 5.0 (19)	4.5 ± 3.1 (11)	5.9 ± 4.6 (18)	12.7 ± 10.6 (48)
PC	May	1.4 ± 0.7 (3)	1.4 ± 0.5 (2)	1.1 ± 0.3 (2)	1.0 ± 0.0 (1)
	September	2.3 ± 1.5 (4)	4.4 ± 5.7 (19)	1.0 ± 0.0 (1)	1.3 ± 0.6 (2)
DC	May	----	4.5 ± 2.9 (9)	4.9 ± 3.4 (12)	----
	September	1.5 ± 0.6 (2)	1.2 ± 0.4 (2)	1.7 ± 1.0 (4)	1.7 ± 1.2 (3)
RS	May	1.7 ± 1.7 (6)	2.3 ± 1.3 (5)	2.3 ± 2.0 (8)	5.6 ± 7.0 (24)
	September	2.2 ± 1.0 (3)	1.2 ± 0.5 (1)	1.5 ± 0.7 (20)	2.0 ± 0.9 (2)
CO	May	----	1.0 ± 0.0 (1)	----	----
	September	----	----	----	----

* Nematodes: ET = *Eustrongylides tubifex*; PC = *Philometra cylindracea*; DC = *Dichelyne cotylophora*; RS = *Raphidascaris* sp.; CO = *Camallanus oxycephalus*.

Table 6. Prevalence (%), mean intensity ± standard deviation and maximum number (max) of nematodes in yellow perch from Lake St. Clair 1993. (Intensity values are not rank transformed.)

Nematode	Prevalence	Intensity (max)
Eustrongylides tubifex	3.0	3.0 (3)
Dichelyne cotylophora	40.0	4.8 ± 4.1 (12)
Raphidascaris sp.	36.7	1.6 ± 1.1 (4)
Camallanus oxycephalus	3.3	1.0 (1)
Haplonema sp.	10.0	1.0 (1)
Rhabdochona sp.	6.7	1.0 (1)

was significantly higher at Saginaw Bay than at Lake St. Clair (X^2 = 90.4, df = 14; F = 12.3, df = 8, 261; $P \leq 0.05$). Raphidascaris sp. had a significantly higher prevalence in yellow perch in May than in September in Saginaw Bay 1992 and Lake St. Clair 1993 (X^2 = 34.8, df = 2, $P \leq 0.05$). Prevalence was lowest in September in Saginaw Bay and intermediate in Lake St. Clair. Lake St. Clair yellow perch had a significantly higher mean intensity of D. cotylophora than yellow perch from September from Saginaw Bay (F = 13.9, df = 2, 51; $P \leq 0.05$). Lake St. Clair yellow perch did not significantly differ in mean intensity of D. cotylophora from Saginaw Bay perch collected in May (F = 0.2, df = 1, 29; $P \leq 0.05$).

Regression analyses between intensity of each nematode species and host length, weight, and age were performed for each location. Intensity of D. cotylophora was linearly related to length of yellow perch at Blackhole in September, 1992 (r^2 = 0.99). However, the regression analysis was based solely on three fish infected with D. cotylophora and, therefore, the biological significance of the relationship is questioned.

No significant difference in prevalence or intensity of nematodes was found between male and female perch from Saginaw Bay. However, male and female fish from Lake St. Clair significantly differed in intensity of infection with D. cotylophora and Raphidascaris sp. Female yellow perch had a higher mean intensity of D. cotylophora (F = 7.5, df =

1, 28; $P \leq 0.05$); male perch had a higher mean intensity of Raphidascaris sp. (F = 7.3, df = 1, 28; $P < 0.05$). Three males were infected with D. cotylophora and two females were infected with Raphidascaris sp. Because of small sample sizes, the biological significance is again questioned.

Eustrongylides tubifex

Third and fourth stage larval Eustrongylides tubifex were found encysted and free in mesenteries, muscle, liver, gonads, and free in the body cavity.

Prevalence of E. tubifex did not vary significantly with month (X^2 = 2.1, df = 1, $P \leq 0.05$) or location (X^2 = 5.4, df = 3, $P \leq 0.05$) of yellow perch collection (Table 4). Mean intensity of E. tubifex did not vary significantly between months in Saginaw Bay (F = 2.4, df = 1, 145; $P \leq$ 0.05). However, mean intensity was higher in fish from September. Mean intensity varied among locations (Table 5). Blackhole had a significantly higher mean intensity (Figure 3) than the other three locations (F = 5.0, df = 3, 145; $P \leq$ 0.05). The mean intensities of E. tubifex in fish from the other locations did not significantly differ.

A significant difference in mean intensity of E. tubifex was detected among fish of separate age classes (F = 7.5, df = 10, 228; $P \leq 0.05$). Age 0 fish were uninfected and, accordingly, differed in mean intensity from other age classes of fish (I - V). All other age classes of yellow

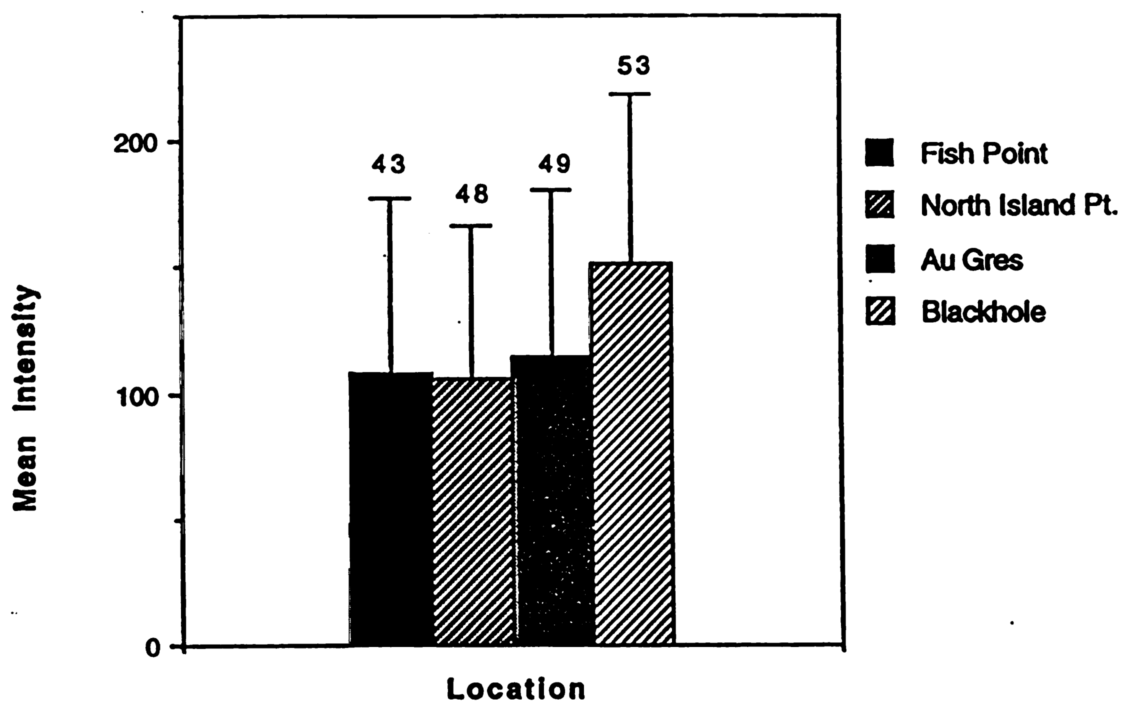

Figure 3. Mean intensity of <u>Eustrongylides</u> <u>tubifex</u> in yellow perch collected from four locations in inner Saginaw Bay, Lake Huron 1992. Intensity data were rank transformed. Bars represent ± SD. Number of infected fish is indicated above each location.

perch did not differ significantly in mean intensity of E. tubifex. However, a trend of increasing intensity with increasing host age was apparent (Figure 4).

A significant difference in mean intensity of E. tubifex among fish length classes was found (F = 5.5, df = 10, 182; $P \leq 0.05$). Fish < 100 mm in length had a significantly lower mean intensity than other size classes (Figure 5). Intensity of E. tubifex increased with increasing host length in fish classes 110 mm and larger. There were no significant differences in mean intensity of E. tubifex between fish length classes 100 mm - 139 mm or between 140 mm and larger.

Philometra cylindracea

Mature and gravid, but not larvigerous, Philometra cylindracea were found free in the body cavity, testes, mesenteries, liver and heart of yellow perch.

There was no significant difference in prevalence of P. cylindracea between months and locations in Saginaw Bay (X^2 = 13.4, df = 7, $P \leq 0.05$) (Table 4). Fish collected in September had a higher mean intensity than fish collected in May, but it was not a significant difference (F = 1.13, df = 1, 35; $P \leq 0.05$) (Table 5). There was no significant difference in mean intensity of P. cylindracea in yellow perch among locations (F = 1.8, df = 3, 35; $P \leq 0.05$) (Table 5).

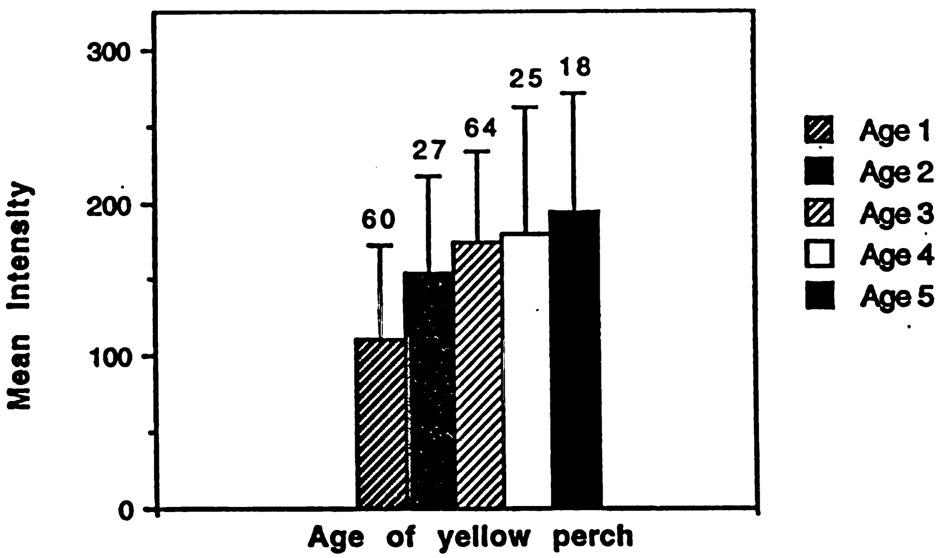

Figure 4. Mean intensity of Eustrongylides tubifex between age classes of yellow perch from Saginaw Bay, Lake Huron 1992. Intensity data were rank transformed. Bars represent ± SD. Fish in age class 0 were uninfected. Number of infected fish is indicated above each age class.

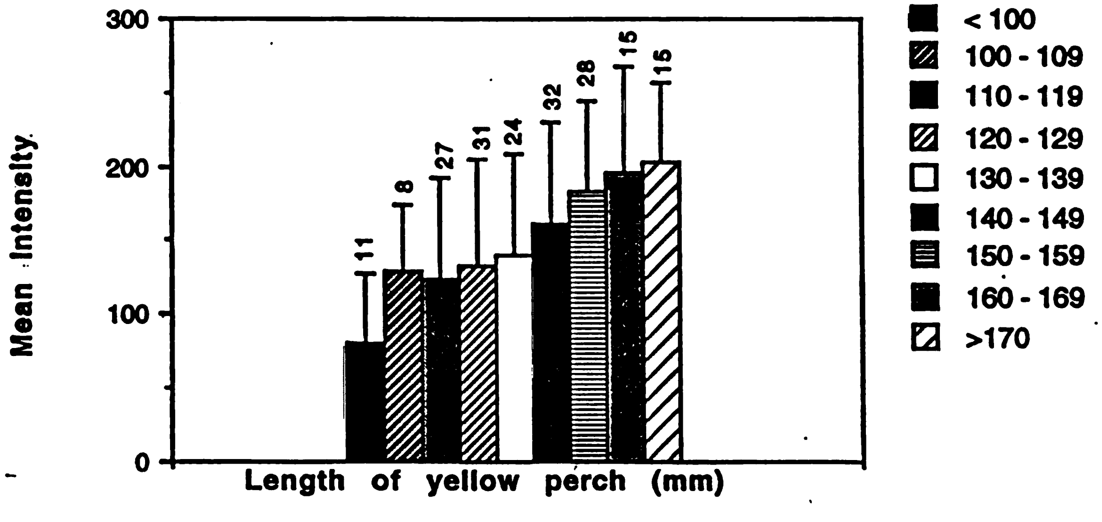

Figure 5. Mean intensity of Eustrongylides tubifex in yellow perch of different length classes (mm). Intensity data were rank transformed. Bars represent ± SD. Number of infected fish is indicated above each length class.

Fish in age classes 0 and V had a significantly higher mean intensity of P. cylindracea than all other age classes ($F = 2.0$, df = 10, 47; $P \leq 0.05$) (Figure 6). No significant difference in mean intensity of fish among other age classes was detected. There were no significant differences in infection of yellow perch between length classes ($F = 0.4$, df = 2, 35; $P < 0.05$).

Dichelyne cotylophora

In May samples, fourth stage larval Dichelyne cotylophora were found in the small intestine and stomach; in September samples, mature males and gravid females and a few fourth stage larvae were found in the small intestine and stomach.

Prevalence of D. cotylophora in yellow perch collected from Saginaw Bay did not differ significantly between months ($X^2 = 1.7$, df = 1, $P \leq 0.05$). Prevalence of D. cotylophora, however, differed among locations and a significantly higher prevalence was recorded from Au Gres ($X^2 = 29.6$, df = 3, $P \leq 0.05$) (Table 4). Fish from Fish Point and Blackhole in May 1992 were uninfected with D. cotylophora (Table 4, Table 5).

A significant difference in mean intensities of D. cotylophora in yellow perch between Saginaw Bay 1992 and Lake St. Clair 1993 (Table 5, Table 6) was detected by ANOVA ($F = 13.9$, df = 2, 51; $P \leq 0.05$). Yellow perch from Lake St. Clair had a significantly higher mean intensity of D.

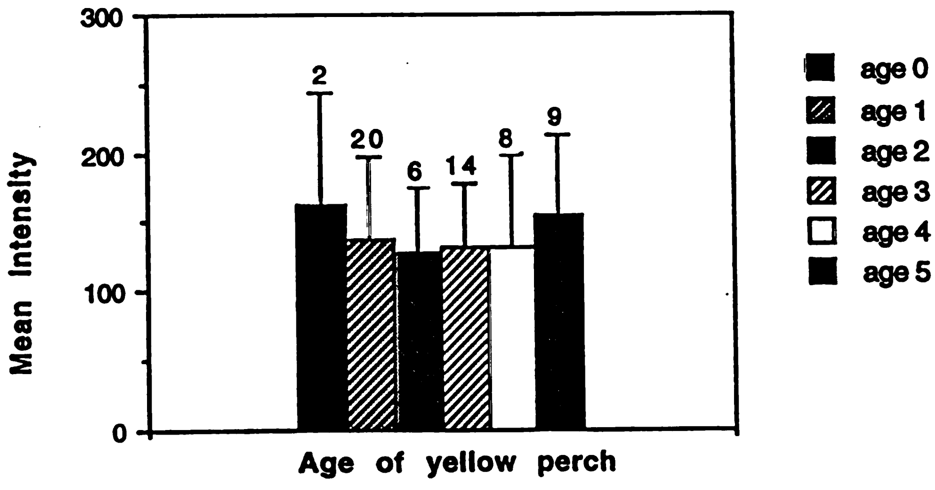

Figure 6. Mean intensity of Philometra cylindracea among age classes of yellow perch from Saginaw Bay, Lake Huron 1992. Intensity data were rank transformed. Bars represent ± SD. Number of infected fish is indicated above each age class.

cotylophora than yellow perch from September from Saginaw Bay. Tukey test revealed that the mean intensity of D. cotylophora from yellow perch in May from Saginaw Bay and Lake St. Clair did not significantly differ, but mean intensity of Saginaw Bay fish from September significantly differed from the others.

In an analysis of Saginaw Bay yellow perch only, a significant difference in mean intensity of D. cotylophora between months ($F = 133.2$, df = 1, 27; $P < 0.05$) and among locations ($F = 78.7$, df = 3, 27; $P < 0.05$) occurred. Differences in mean intensity of D. cotylophora between months are dependent on location of fish collection ($F = 88.3$, df = 3, 27; $P < 0.05$). In May, yellow perch were uninfected at Fish Point and Blackhole and, therefore, significantly differed from the other locations. Mean intensity of D. cotylophora did not significantly differ between Au Gres and North Island Point. Fish from the four locations in September did not significantly differ in mean intensity of D. cotylophora.

No significant difference in mean intensity of D. cotylophora occurred in fish from different age classes ($F = 1.0$, df = 10, 34; $P \leq 0.05$). Age class 0 fish were uninfected and other age classes had low intensity. There was no significant difference in intensity of D. cotylophora in fish of different length classes ($F = 1.7$, df = 2, 27; $P < 0.05$).

Raphidascaris sp.

Fourth stage larval Raphidascaris sp. were found free in the liver, and encysted in the liver, mesenteries and intestinal wall.

The prevalence of Raphidascaris sp. in yellow perch from Saginaw Bay significantly differed between months when data were combined (X^2 = 34.9, df = 1, $P \leq 0.05$) but not among locations (X^2 = 3.1, df = 3, $P \leq 0.05$). The prevalence of infection was higher in May than in September 1992 (Table 4).

No significant difference in mean intensity of Raphidascaris sp. was detected (F = 1.3, df = 2, 87; $P \leq$ 0.05) between fish from Saginaw Bay 1992 and Lake St. Clair 1993 (Table 5, Table 6). The mean intensity of Raphidascaris sp. in fish collected from Saginaw Bay did not significantly differ between months (F = 0.2, df = 1, 56; $P \leq 0.05$) (Table 5). There was no significant difference in mean intensity of Raphidascaris sp. among locations in Saginaw Bay (F = 0.6, df = 3, 56; $P \leq 0.05$) (Figure 7).

Fish in age class I from Saginaw Bay had a significantly lower prevalence and mean intensity (Figure 8) of Raphidascaris sp. than fish in other age classes (F = 3.3, df = 4, 74; $P \leq 0.05$). Mean intensities of fish in other age classes did not significantly differ. A significant difference in mean intensity of Raphidascaris sp. among age classes of fish from Lake St. Clair 1993 was

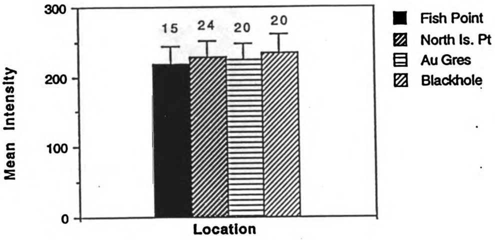

Figure 7. Mean intensity of Raphidascaris sp. in yellow perch from four locations in inner Saginaw Bay, Lake Huron 1992. Intensity data were rank transformed. Bars represent ± SD. Number of infected fish is indicated above each location.

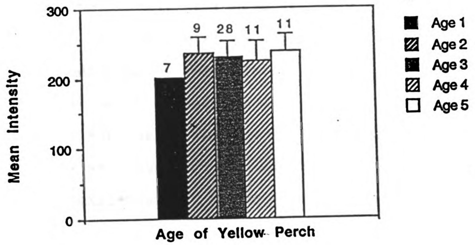

Figure 8. Mean intensity of Raphidascaris sp. among age classes of yellow perch from Saginaw Bay, Lake Huron 1992. Intensity data were rank transformed. Bars represent ± SD. One age class 0 fish was infected. Number of infected fish is indicated above each age class.

not detected.

A difference in intensity of Raphidascaris sp. in fish of different length classes was detected (F = 4.4, df = 3, 56; $P \leq 0.05$). The Tukey test revealed overlapping similarities in intensities, implying that there was not enough information to determine if a relationship between parasite intensity and host length exists. Fish of lengths less than 120 mm had lower mean intensities than fish greater than 120 mm, but this was not significant.

Infrequent Nematodes

Mature and gravid Camallanus oxycephalus were found in the intestine; larval Haplonema sp. were found encysted in the stomach wall, mesenteries and muscle; and mature and gravid Rhabdochona sp. were recovered from the intestine.

Several nematode species were not included in the statistical analyses. The one unidentified nematode from Saginaw Bay was found only in May 1992 at Fish Point. Camallanus oxycephalus was found only in May 1992 at North Island Point in Saginaw Bay (Table 4, Table 5). Yellow perch from Lake St. Clair also had low prevalence and intensity of C. oxycephalus. Haplonema sp. and Rhabdochona sp. occurred infrequently and were found only in Lake St. Clair (Table 6). Only one fish from Lake St. Clair was infected with E. tubifex; none were infected with P. cylindracea.

DISCUSSION

It is generally accepted that the parasite fauna as well as parasite distribution in aquatic ecosystems are influenced by the interaction of abiotic and biotic factors (Wisniewski 1958; Esch 1971; Marcogliese and Cone 1991). Based on the present study and studies by Bangham (1955) and Dechtiar *et al.* (1988), the nematode fauna of Saginaw Bay and Lake Huron proper are similar. Bangham (1955) found five species of nematodes in yellow perch from South Bay, Lake Huron proper, and Manitoulin Island; Dechtiar *et al.* (1988) found four species of nematodes in perch from Lake Huron proper. Of the five nematode species identified from Saginaw Bay yellow perch, only Camallanus oxycephalus was not found in the Lake Huron proper studies.

Saginaw Bay and Lake St. Clair differ in size and water quality and it is apparent that fish collected from Lake St. Clair differ from Saginaw Bay yellow perch in nematode fauna as well as parasite abundance (Table 4, Table 5, Table 6). Because these fish were collected in different years, it is difficult to determine if the differences reflect location or year. In addition, only 30 fish were collected from Lake St. Clair and these fish were significantly larger than those collected from Saginaw Bay.

Study locations in inner Saginaw Bay, Lake Huron, vary in water quality, depth, and distribution of potential hosts of the nematodes studied. Time of year of yellow perch collection and fish diet probably influence the composition of the nematode fauna. Distribution and abundance of nematodes in yellow perch from different locations and months in Saginaw Bay may vary with differences in these conditions.

Yellow perch have a higher mean intensity of E. tubifex at Blackhole than at other Saginaw Bay locations (Figure 3). A survey of Saginaw Bay oligochaetes and benthic fauna revealed that Limnodrilus hoffmeisteri is present in high numbers in the Blackhole area (Brinkhurst 1967). Historically, as Saginaw Bay became more polluted and eutrophic with increased inputs from its tributaries, the benthic invertebrates were replaced by pollution-tolerant organisms such as L. hoffmeisteri (Brinkhurst 1967; Diaz 1980; Michigan Department of Natural Resources 1988). Limnodrilus cervix Brinkhurst 1963 and L. hoffmeisteri are among the most abundant benthic invertebrate taxa in Saginaw Bay (Michigan Department of Natural Resources 1988).

The increased abundance of tubificid oligochaetes at Blackhole explains the greater prevalence and intensity of E. tubifex at that location. Locations with an abundance of tubificid oligochaetes would have high prevalences and intensities of Eustrongylides spp. in fish collected from those localities since the oligochaetes make up a larger portion of the fish diet (Kaeding 1981; Crites 1982; Hirshfield *et al.* 1983; Measures 1988b).

Yellow perch collected from Saginaw Bay in September had a higher intensity of P. cylindracea than fish collected in May 1992. Philometra cylindracea has a one year life cycle and declines rapidly in late June through July or August after the females release their larvae and subsequently die (Molnar and Fernando 1975; Crites 1982). Abundance then increases in September and early October as yellow perch ingest copepods infected with the new generation of larvae (Crites 1982). The higher mean intensity of P. cylindracea in fish from September may be directly related to the appearance of the new generation.

No larvigerous P. cylindracea were recovered. This may be attributed to month of yellow perch collection. Female P. cylindracea become larvigerous and release their larvae in late June in Lake Erie (Crites 1982). Yellow perch in the present study were apparently collected prior to the development of the larvae within the female nematodes.

Crites (1982) associated the presence of P. cylindracea in yellow perch with good water quality since this parasite requires a copepod intermediate host in its life cycle. However, a study by the Michigan Department of Natural Resources (1988) found an abundance of cyclopoid copepods in more eutrophic waters near the mouth of the Saginaw River. The lack of significant difference in prevalence and intensity between locations could indicate that both pollution tolerant and intolerant copepod species may be suitable intermediate hosts.

Although Cannon (1973) observed seasonal fluctuations in prevalence of *D. cotylophora* in yellow perch with a maximum in June and August, Baker (1984b) showed no marked seasonality in prevalence of infection. In the present study, there was no significant difference in prevalence of *D. cotylophora* in yellow perch between months in Saginaw Bay. However, mean intensity was significantly higher in May 1992 than in September. This implies that *D. cotylophora* are lost from perch over the summer. Baker (1984b) found a similar seasonal maturation cycle.

The prevalence of *D. cotylophora* in yellow perch from Au Gres was significantly higher than at other locations. Baker (1984b) suggested that aquatic insect larvae may be paratenic hosts for *D. cotylophora*. The higher concentration of aquatic insect larvae such as *Chironomus* spp. at Au Gres may explain the higher prevalence of *D. cotylophora* at this location. However, this does not explain the significantly lower prevalence of this nematode at Blackhole which also has an abundance of *Chironomus* spp. larvae.

Baker (1984b) found that in late August and September yellow perch were infected with small numbers of *D. cotylophora* which mature immediately. This may be the main source of infection of yellow perch from Blackhole and Fish Point with this nematode since fish from these locations were uninfected in May 1992 and fish collected in September had low prevalence and intensity (Table 4, Table 5). A second generation of *D. cotylophora* may be infecting yellow perch in August or September, but the larger generation of *D. cotylophora* larvae which should be accumulated in fall and winter was not acquired by fish from these locations and, thus, was not found in the May sample.

Adult *Raphidascaris* sp. may live for one year within the definitive hosts (Moravec 1970b; Smith 1986), while fourth stage larvae often live for two or more years and are common in yellow perch throughout the year. Prevalence of *Raphidascaris* sp. in fish from Saginaw Bay was significantly higher in May than in September 1992. Yellow perch can be infected directly by ingesting eggs or indirectly by ingesting invertebrate paratenic hosts such as chironomids, amphipods or oligochaetes (Moravec 1970a, 1970b; Smith 1984b, 1986).

When female nematodes begin producing eggs in early May, an increase in intensity of *Raphidascaris* sp. in yellow perch should occur in subsequent months. Adults cease egg production and then are lost from the definitive host in summer and fall (Moravec 1970b; Smith 1986). Either the invertebrate hosts or the nematode larvae do not survive past summer (Smith 1986). Thus, lower prevalence in the September sample from Saginaw Bay is probably due to an abrupt decrease in infective stages at the same time as uninfected young-of-the-year perch dilute the sample.

Although there was no significant difference in prevalence or mean intensity of *Raphidascaris* sp. among locations, there was some variation (Table 4, Figure 7).

Because chironomids, amphipods and oligochaetes may act as paratenic hosts for Raphidascaris sp. the distribution of this nematode in Saginaw Bay may vary with the abundance of the paratenic hosts. Yellow perch from Fish Point had low prevalence and intensity of Raphidascaris sp.; North Island Point, Au Gres, and Blackhole had higher prevalences and intensities. There is a greater concentration of chironomids and oligochaetes in the areas with higher prevalences and intensities of Raphidascaris sp. which may explain the higher prevalence and mean intensity of this nematode at North Island Point, Au Gres, and Blackhole.

The diet of yellow perch is a factor influencing the distribution and abundance of nematodes among size and age classes of fish. Initially, age 0 yellow perch are planktivorous, but as size and age increase they become both planktivores and benthic feeders (Cooper *et al.* 1978; Crites 1982). Changes in feeding habits of yellow perch are reflected in the infection pattern of E. tubifex in different age-size classes of yellow perch. Larval E. tubifex have a long life span and can be transmitted from one fish to another (Cooper *et al.* 1978) and the increase in intensity (Figure 4, Figure 5) and prevalence of E. tubifex with age and size of the host reflects an increase in piscivory and an accumulation of worms over time.

The infection pattern with E. tubifex in age classes of yellow perch indicates that yellow perch become infected as age 0 fish within the first year of life (Figure 4). In the present study, age 0 yellow perch were uninfected. Cooper *et al.* (1978) and Crites (1982) found that age 0 yellow perch from Lake Erie were infected by August, but had low prevalences and intensities of infection. Salz (1989) found age 0 yellow perch from Saginaw Bay infected with E. tubifex by September, but prevalence was only 0.5%.

A similar pattern of infection of age classes was seen with Raphidascaris sp. One age 0 yellow perch was infected with Raphidascaris sp. and age class I fish had low prevalence and mean intensity. Since fourth stage larvae live at least two years, Raphidascaris sp. accumulates over time and, thus, intensity increases with age-size class of the fish (Figure 8) (Moravec 1970a, 1970b; Bauer and Zmerzlaja 1973; Dergaleva and Markevich 1976; Smith 1984b, 1986). Smith (1986) also attributed increased intensity of Raphidascaris sp. to a greater volume of invertebrates in the diets of larger perch.

Age class I yellow perch had the lowest prevalence and mean intensity of Raphidascaris sp. (Figure 8). This may represent an age class of fish which was not heavily infected in the previous fall before adult Raphidascaris sp. ceased egg production or before the loss of infected invertebrates.

Intensity of Raphidascaris sp. in yellow perch differed in fish of different lengths. Although it was not significant, larger fish (> 120 mm) typically had higher intensities of Raphidascaris sp. than smaller fish. This result agrees with other studies which found increased intensity in larger and older fish and represents an accumulation of worms over time and increased in intake of invertebrate food items.

The feeding activity of yellow perch also may explain the infection pattern with P. cylindracea. Since yellow perch are initially planktivores and feed throughout their lives on copepods, prevalence and intensity of infection with P. cylindracea in yellow perch should be uniform throughout all age-size classes. However, in Saginaw Bay 1992, age class V had a significantly higher intensity than other age classes (Figure 6). This may indicate that larger yellow perch consume an increased volume of copepods. An alternate explanation is that P. cylindracea can be transferred from one fish host to another so that as yellow perch become more piscivorous the intensity of infection with P. cylindracea increases. This would explain the elevated intensity of P. cylindracea in age class V yellow perch. Although the transmission of P. cylindracea from one fish host to another has not been demonstrated, it has been demonstrated for P. obturans Prenant 1886 in pike, Esox lucius, perch, Perca fluviatilis L., and rudd, Scardinius erythrophthalmus L. (see Molnar 1976; Moravec and Dykova 1978).

Even though age 0 fish were uninfected, there was no significant difference in prevalence or intensity of infection with D. cotylophora among age-size classes of yellow perch from Saginaw Bay. Yellow perch are becoming infected at a young age, but the only known intermediate host is a small cyprinid fish (Baker 1984b). Young yellow perch which are not yet piscivorous are equally as infected as older yellow perch. This implies that yellow perch might be infected by another means; perhaps aquatic insect larvae or other invertebrates are important hosts.

Since _D. cotylophora_ has a one year life cycle there was no accumulation of _D. cotylophora_ in older or larger yellow perch, which is consistent with Baker (1984a, 1984b). Age class V fish had a slightly higher intensity, but this was probably due to increased volume of food eaten by larger fish (Cannon 1973). No significant trend of increasing prevalence or intensity was found.

Yellow perch from Saginaw Bay are heavily infected with _E. tubifex_. Reduced growth rate of yellow perch and fish mortality have resulted from _E. tubifex_ infection (Allison 1966; Crites 1982; Salz 1989). Although yellow perch have lower prevalence and intensity of _P. cylindracea_, it is present in yellow perch throughout Saginaw Bay. Crites (1982) also linked reduced fish growth to infection of yellow perch with _P. cylindracea_. For these reasons yellow perch from Saginaw Bay should not be used for stocking other systems.

If Saginaw Bay yellow perch were used for stocking, it is likely that _E. tubifex_ could effectively establish itself in systems that contain tubificid oligochaetes and are visited by piscivorous birds. *Philometra cylindracea* could also become established easily in a system containing copepods; this would be especially rapid in the case of a zooplankton bloom. Thus, if these fish were transferred to uninfected areas inhabited by potential hosts, *E. tubifex* and *P. cylindracea* could become established. This would most likely be harmful to the animals associated with the new system.

Fish collected from Lake St. Clair had low prevalences and intensities of *E. tubifex* and were uninfected with *P. cylindracea* which implies that this may be a more suitable location to obtain fish for stocking. But caution should also be used since other parasites could have pathological effects on animals in a new system.

CONCLUSIONS

The distribution of parasites in host populations is of interest because it often relates to abiotic and biotic factors of the system. *Eustrongylides tubifex* can be used as an indicator species of the level of eutrophication of an aquatic system. In eutrophic waters, *E. tubifex* increases because the number of tubificid oligochaetes increases.

Overall, most nematode infection patterns in yellow perch from Saginaw Bay, Lake Huron, can be explained by the distribution of hosts and by the life histories of the hosts and parasites. Influences on the distribution of hosts are water quality, depth, and time of year. In Saginaw Bay, Blackhole is the most eutrophic of all the study locations with the highest tubificid oligochaete abundance. These factors contribute to the elevated prevalence and intensity of *E. tubifex* at Blackhole.

Au Gres is less eutrophic than Blackhole yet has high numbers of chironomids. Yellow perch from Au Gres had the highest prevalence of infection with *D. cotylophora*. The distribution of *Raphidascaris* sp. in Saginaw Bay also is influenced by invertebrate distribution. Yellow perch had high prevalence and intensity of *Raphidascaris* sp. at Blackhole, and high prevalence at Au Gres and North Island Point. These locations have high numbers of invertebrates.

Time of year of yellow perch collection is a factor in nematode abundance as well as the maturation of the nematodes (Dogiel 1962). Prevalence of *Raphidascaris* sp. was higher in May 1992 in Saginaw Bay but prevalences of *E. tubifex*, *P. cylindracea* and *D. cotylophora* did not vary significantly with month of yellow perch collection. Mean intensities of larval nematodes, *E. tubifex* and *Raphidascaris* sp., did not significantly differ between months of perch collection in Saginaw Bay. Mean intensities of adult nematodes in yellow perch varied with month. Mean intensity of *P. cylindracea* was higher in September than in May; the mean intensity of *D. cotylophora* was significantly higher in May than September 1992.

Yellow perch of different size and age classes have different infection patterns which are influenced primarily by fish diet. Accumulations of *E. tubifex* and *Raphidascaris* sp. occurred in larger and older yellow perch from Saginaw Bay. Age class V fish had higher intensity of *P. cylindracea*, although there was no difference in infection of different sized fish.

Because of the high prevalence and mean intensity of *E. tubifex* and the presence of *P. cylindracea* in yellow perch, fish from inner Saginaw Bay should not be used for stocking other systems.

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